

X-ray Probes of the Universe at Intermediate Redshifts

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X-ray Probes at Intermediate Redshift

- # Cosmological studies in the X-ray Band
- # An example of an intermediate-redshift problem best solved in the X-ray band
 - v X-ray/submm studies
- # Observational requirements

Cosmological Studies in the X-ray Band

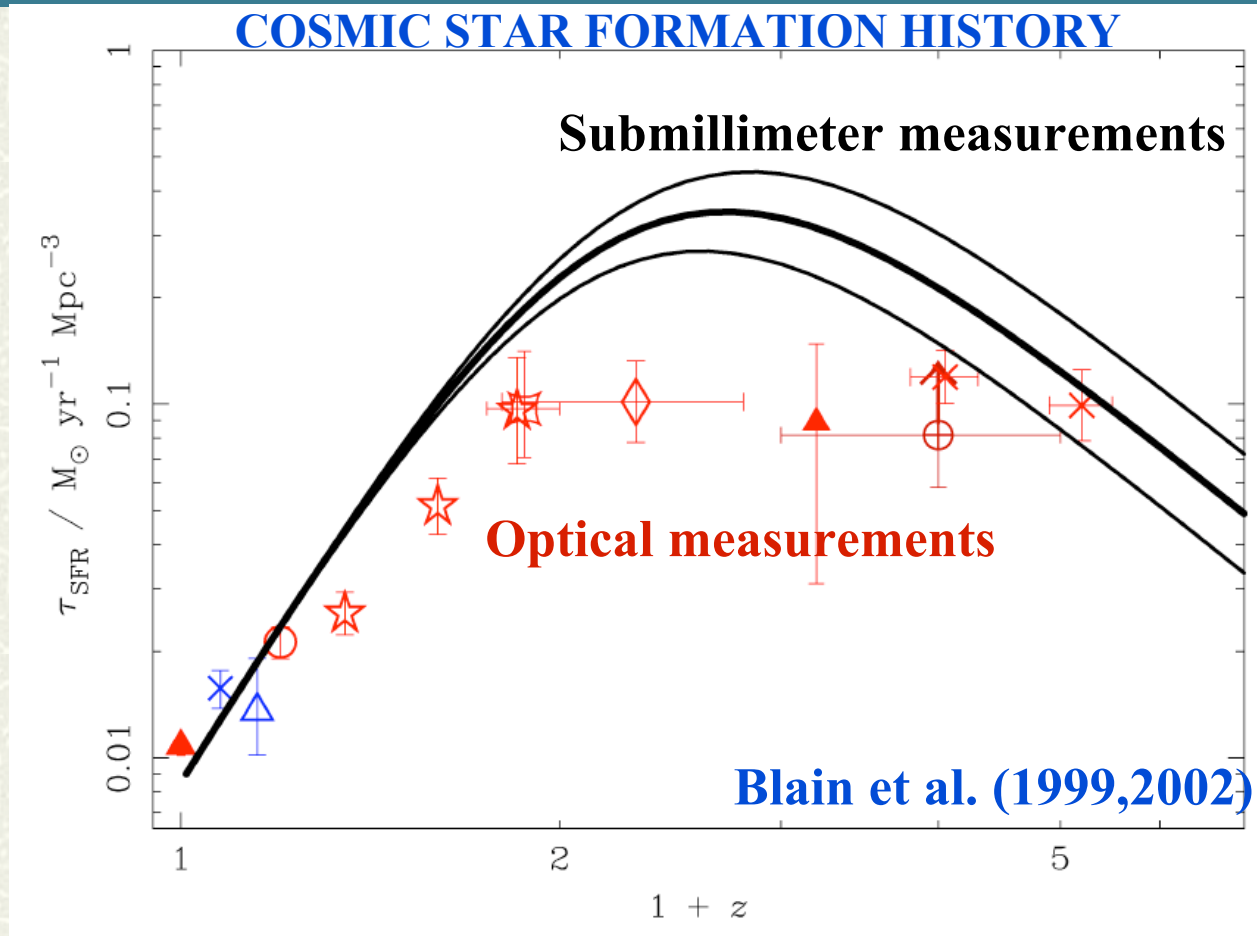
Star-forming Galaxies:

- ✓ Accreting binary populations can be probed from $0.1 < z < 1.0$ with moderate-to-deep Chandra imaging surveys
- ✓ Statistical analyses allow probes of vigorously star-forming galaxies at $z > 3$

AGN

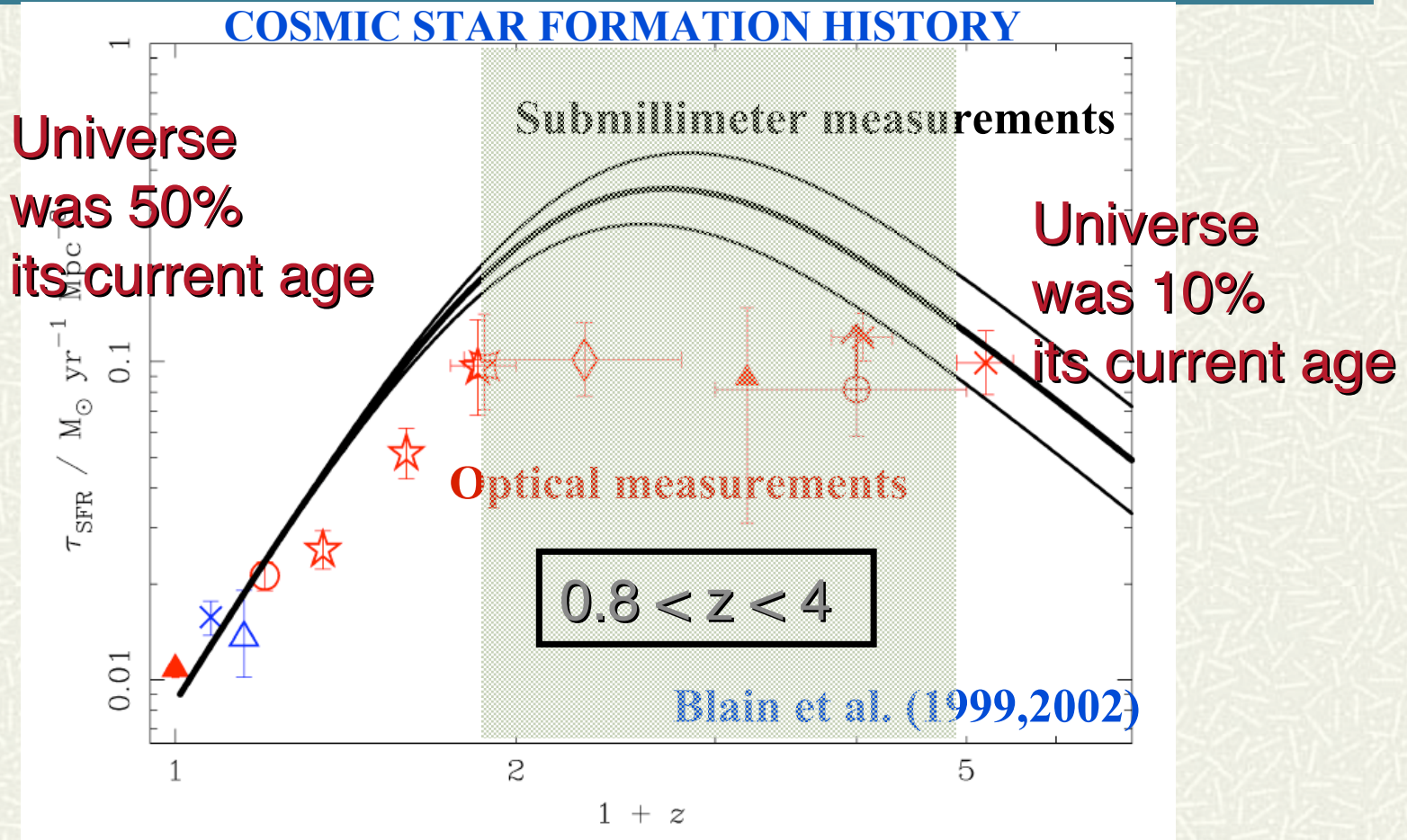
- ✓ Deepest current X-ray surveys may detect Seyfert-luminosity AGN to $z \sim 10$

Intermediate redshift??



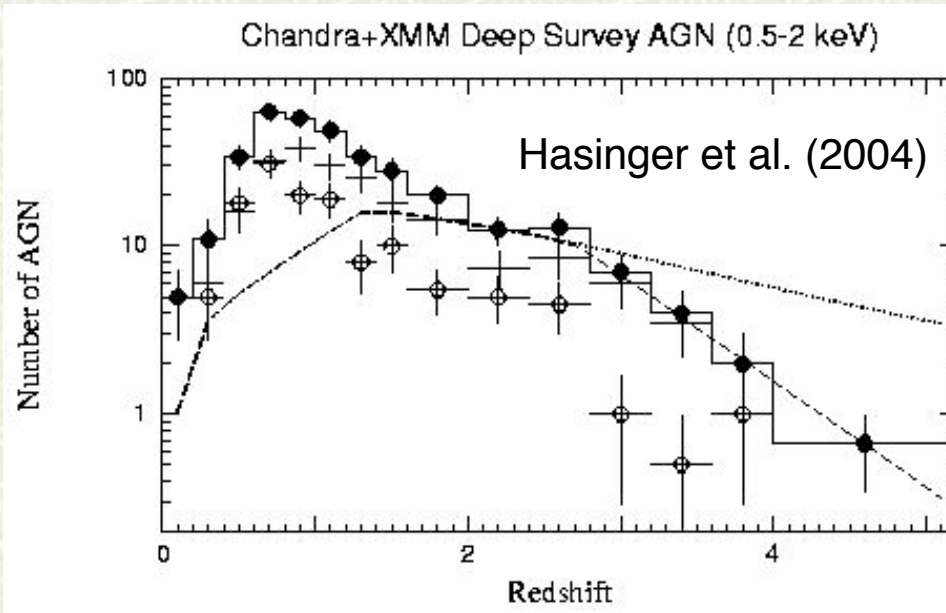
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Intermediate redshift??



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X-ray Emission from the Universe



Contributors to the 2-10 keV XRB

(Hornschemeier et al. 2003,
Moretti et al. 2003, Bauer et al. 2004)

- X-ray obscured AGN: 45%
- X-ray unobscured AGN: 38%
- Galaxies: 3%
- Clusters: ~5%

TOTAL: 91%

The high-energy Universe is dominated by accreting supermassive black holes at intermediate redshift

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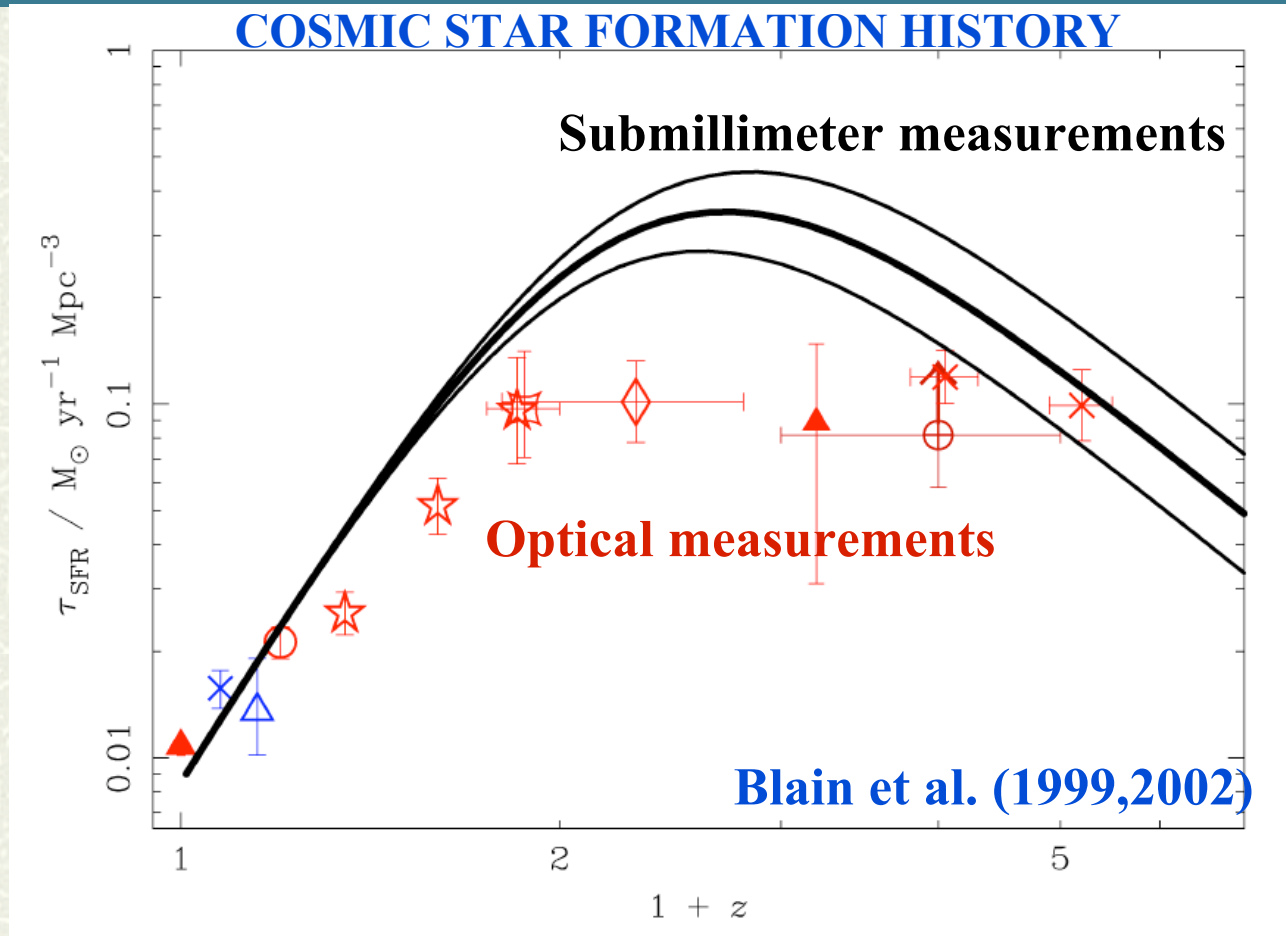
Coeval Growth of SMBH and Galaxy Bulges

- # SFR in spheroids expected to be found around luminous (i.e., *growing*) SMBH
- # Based on standard assumptions, the ratio of starburst to AGN emission is a factor of ~ 5 (Page et al. 2000)
- # Highest SFR often occurs in highly obscured regions in galaxies (e.g., Kennicutt et al. 1998) \diamond FIR Emission

The typical SCUBA source (Blain et al. 2002)

- # Negative k-correction for FIR emission at $1 < z < 10$
- # There are 200 “blank-field” SCUBA-detected sources
- # Typical members of the submm population require 10 hour exposures with SCUBA
- # The few with measured z are “intermediate”

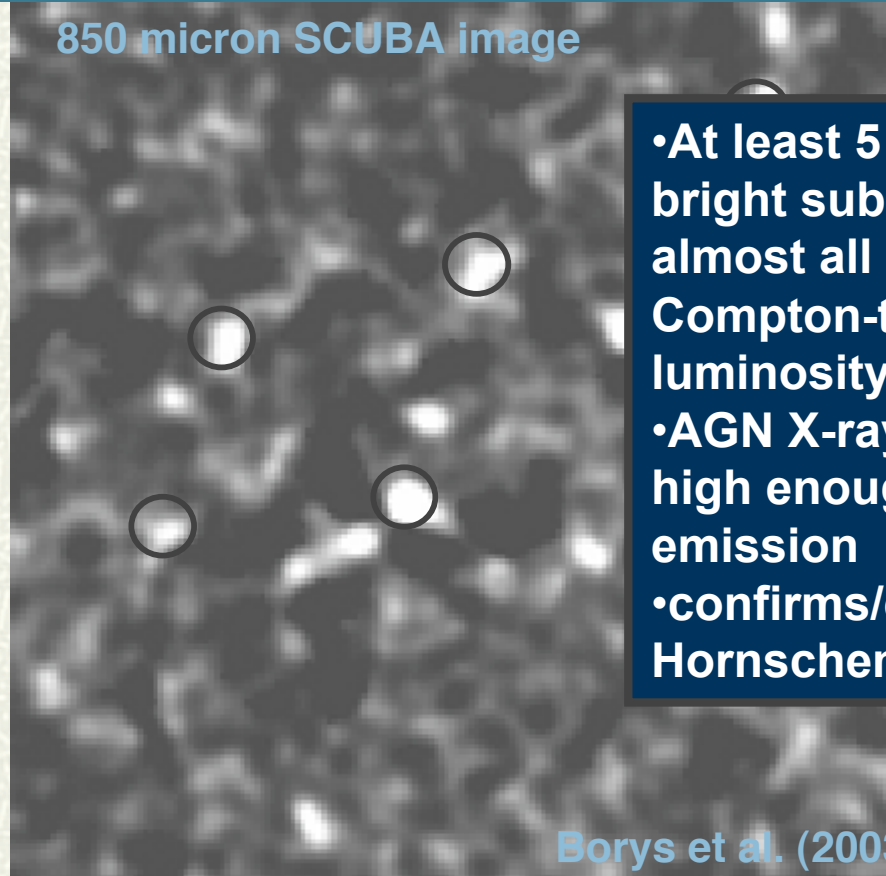
SFR density of the Universe



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The Submillimeter Galaxy Population

850 micron SCUBA image



- At least 5 are AGNs (38% of bright submm galaxies) ◇ almost all appear to be Compton-thin moderate-luminosity AGNs
- AGN X-ray luminosity not high enough to power submm emission
- confirms/extends results of Hornschemeier et al. (2000)

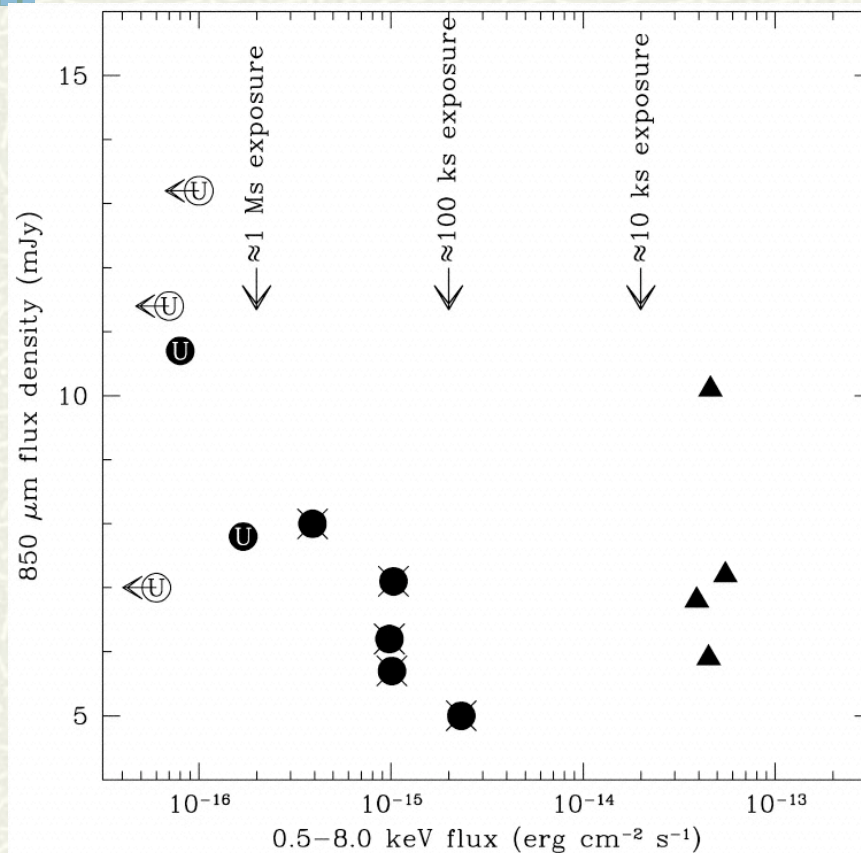
Borys et al. (2003)

7 (54%) of the sources are X-ray detected

(Alexander et al. 2003)

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The Submillimeter Galaxy Population



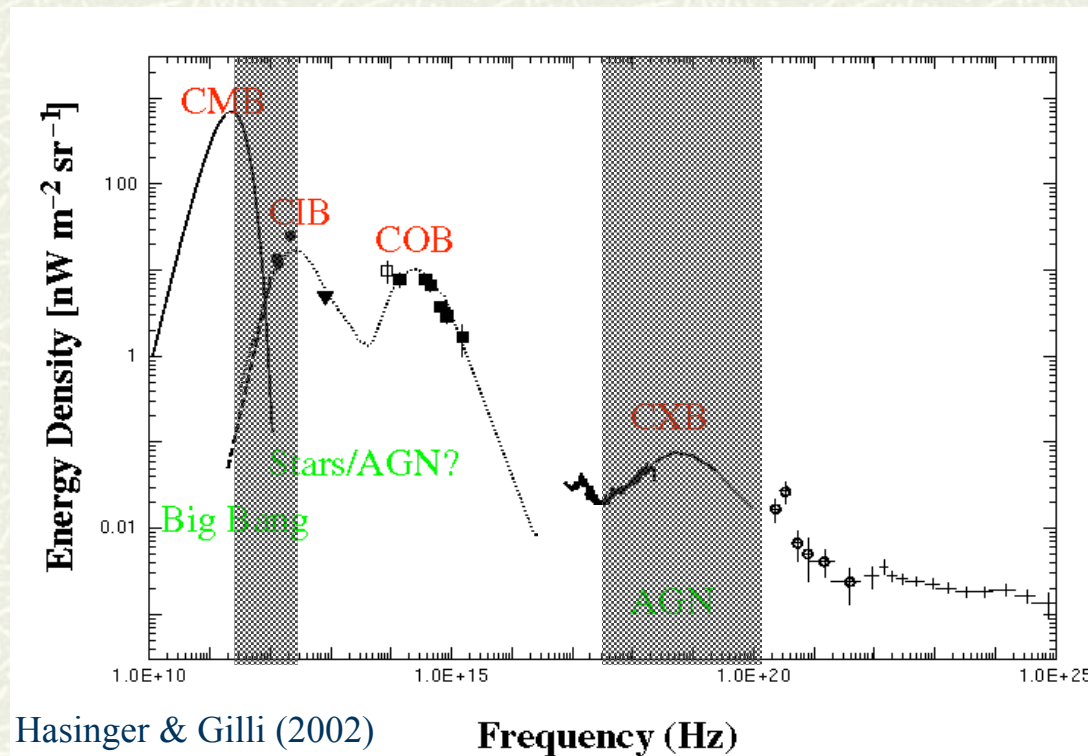
- Follow-up at other wavelengths prohibitive (typically optically faint, $I > 24$)
- Detailed X-ray spectroscopy to ascertain Compton-thick nature and characterize star-formation component

Alexander et al. 2002

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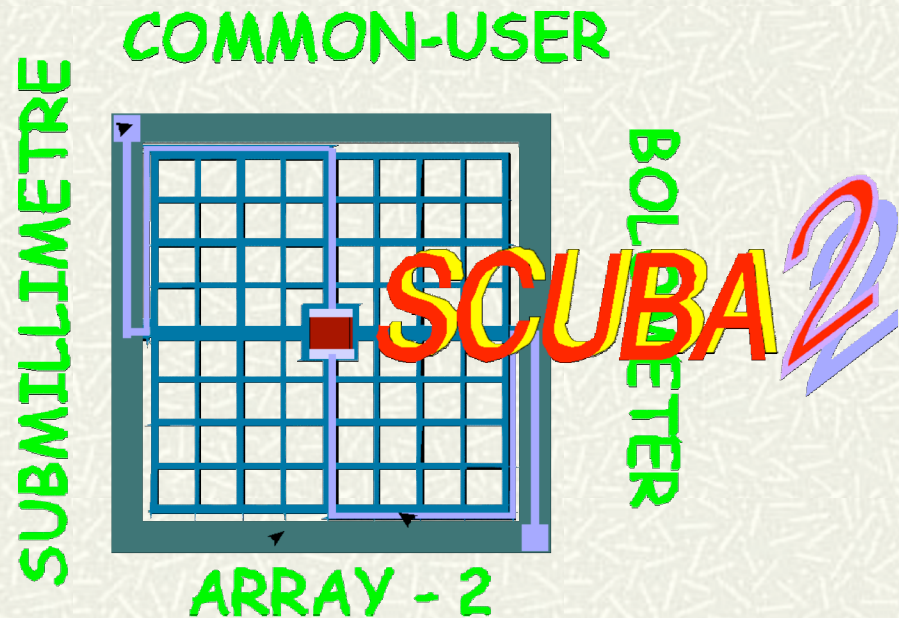
Extragalactic Background Radiation (EBR) Studies

Two wavebands have remained observationally elusive for the longest time: hard X-rays and the submillimeter



The Next Generation of Submillimeter Instruments

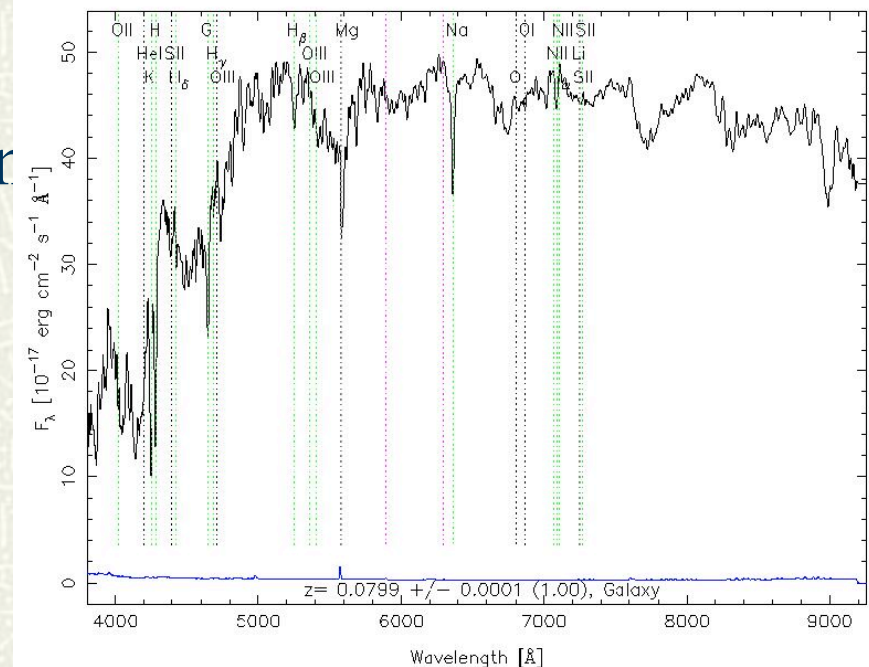
- # SCUBA2 (40X FOV + 8X sensitivity)
- # Will increase # of submm detections but won't secure redshifts, etc.
- # 64 x 12-m Atacama Large Millimeter Array (Chile) \diamond 30 μ arcsec resolution



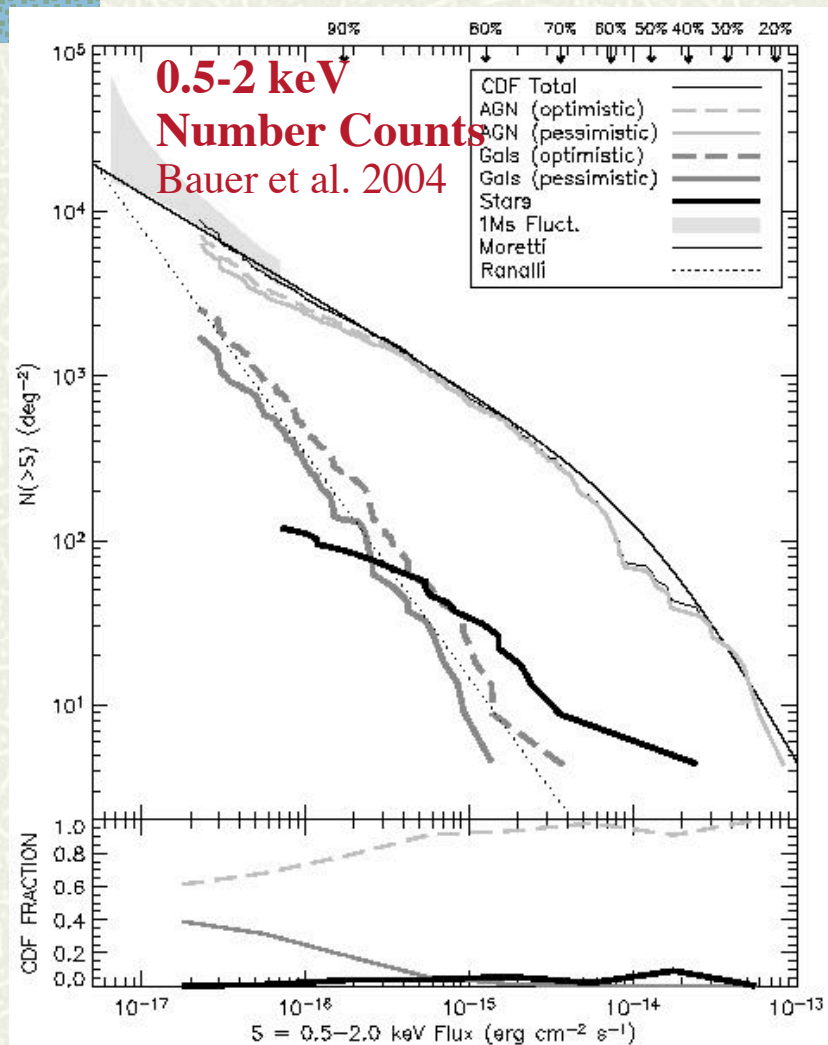
Con-X Spectroscopy of Elusive AGN

- “Elusive” AGN (e.g., P3, Comastri et al.)
- Plausibly an optical aperture effect (Moran et al. 2003)
- May be a class of accreting SMBH that is missed in optical surveys

SDSS Spectrum of
X-ray Luminous Galaxy
(Hornschemeier et al. 2004)

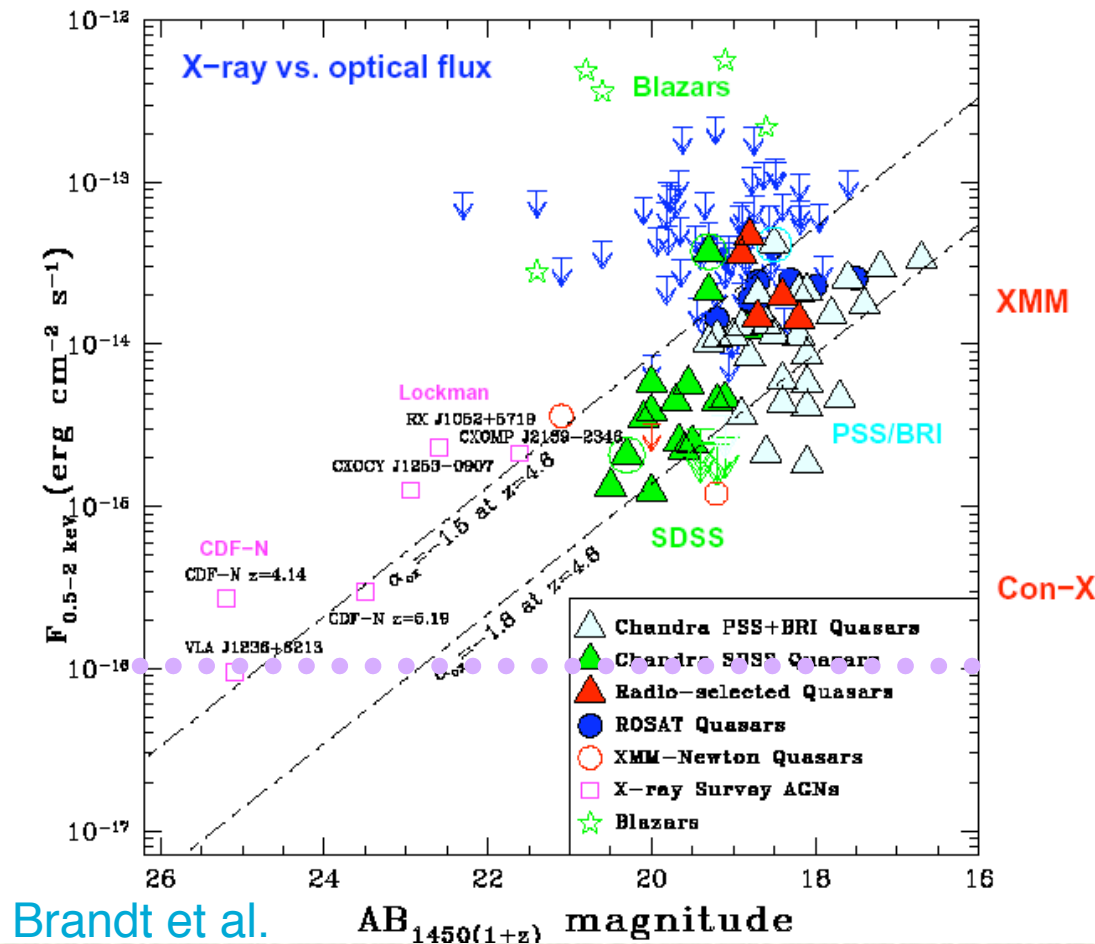


Observational Requirements for Intermediate-Redshift Studies



- X-ray flux of typical X-ray obscured submm source:
 $\sim 1 \times 10^{-16}$ erg cm $^{-2}$ s $^{-1}$ (0.5-2 keV)
- Confusion if spatial resolution $> 5''$

The first black holes in the Universe ($z > 4$)



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